

# ACUTE RADIATION SYNDROME: Diagnosis and Treatment



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# Objectives

- Provide a review of radiation basics and acute radiation sickness
- Discuss diagnostic tools and triage tools for Acute Radiation Syndromes
- Discuss management of Acute Radiation Syndromes

# What is Radiation?

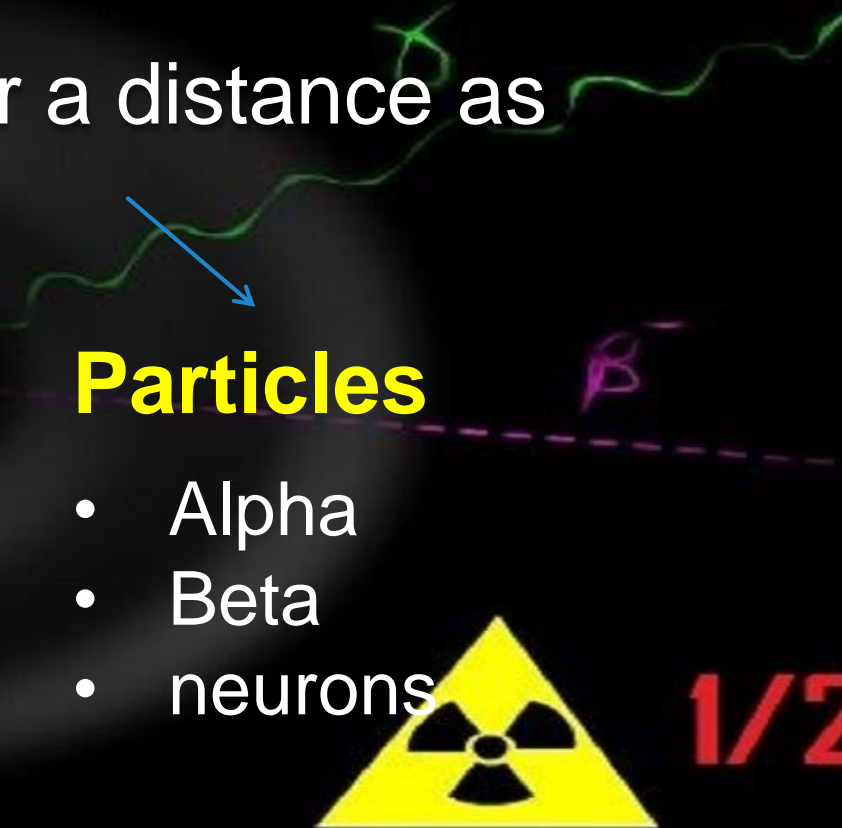
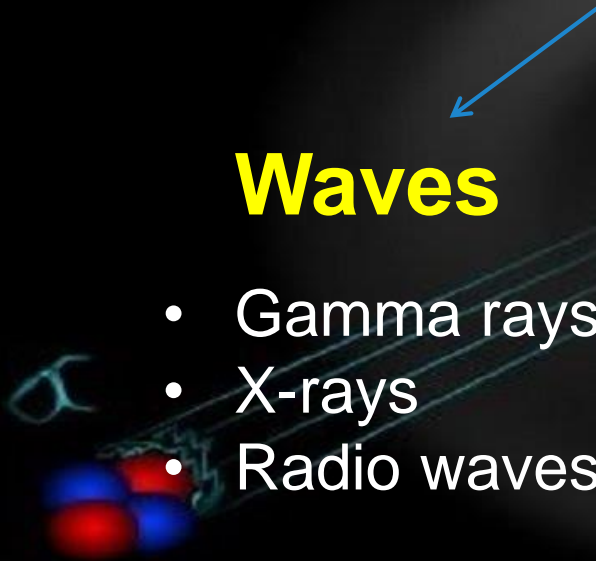
Energy traveling over a distance as

## Waves

- Gamma rays
- X-rays
- Radio waves

## Particles

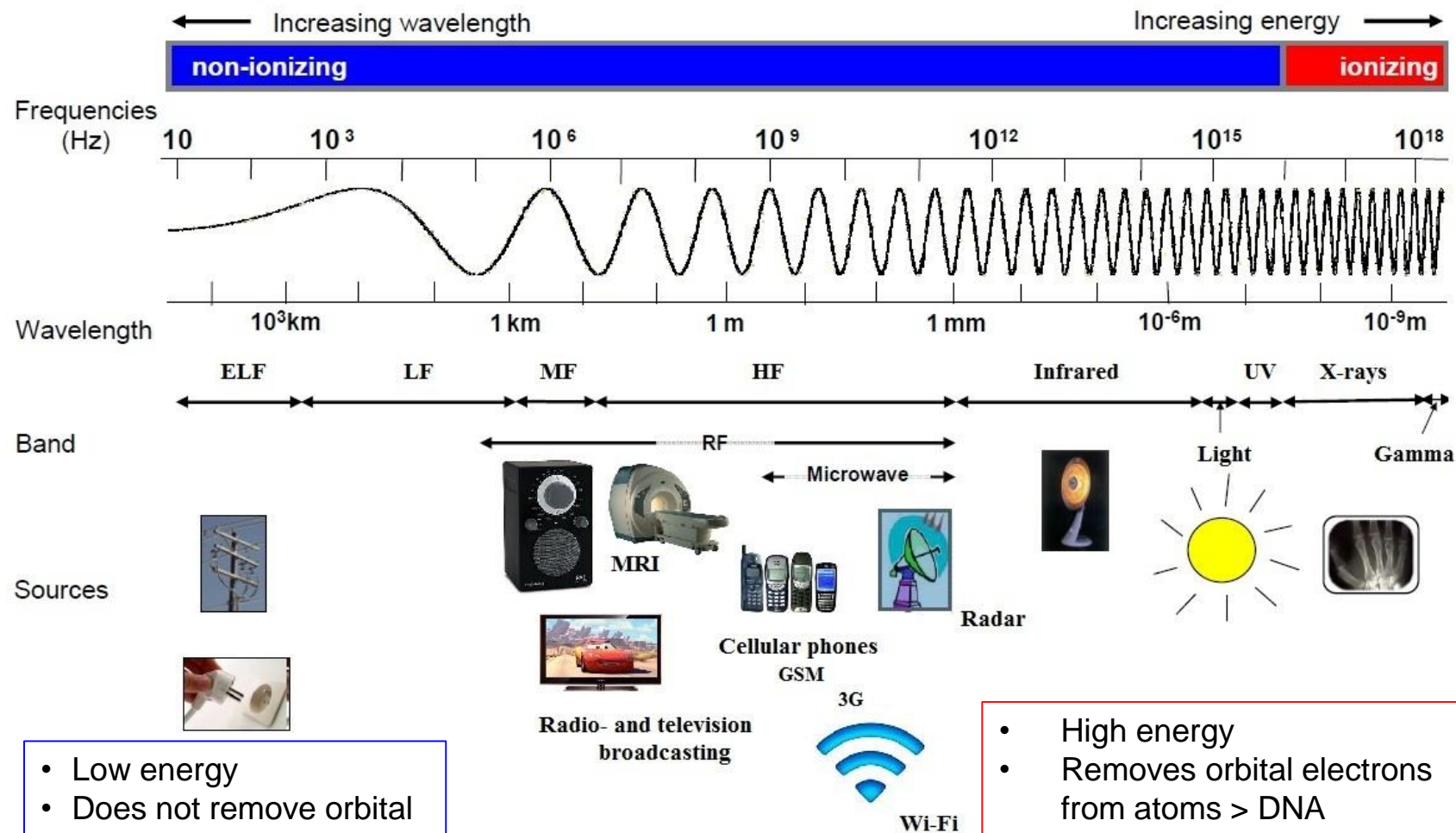
- Alpha
- Beta
- neutrons



1/2

# Non-ionizing vs Ionizing Radiation

## THE ELECTROMAGNETIC SPECTRUM



- Low energy
- Does not remove orbital electrons from atom

- High energy
- Removes orbital electrons from atoms > DNA damage

# Radioactive Decay

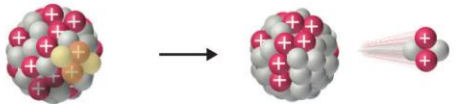
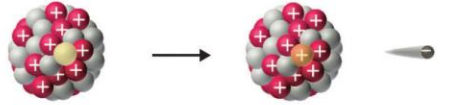
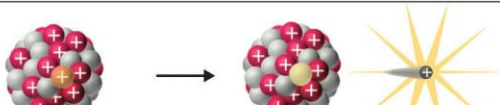
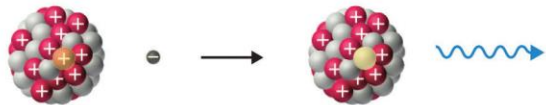
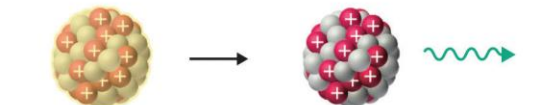
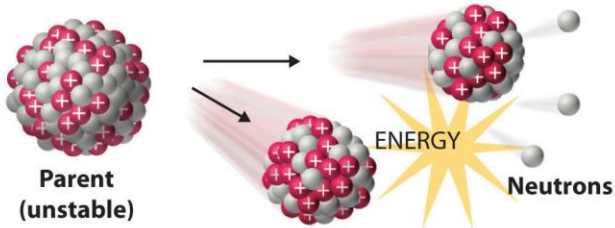
- ☉ Process to

- ☉ Remove excess energy from atomic nuclei

- ☉ Nuclei emit rays or particles to decrease nuclear energy

- ☉ Radioactive materials have unstable nuclei with excess energy



Decay Type	Radiation Emitted	Generic Equation	Model		
Alpha decay	${}^4_2\alpha$	${}_Z^AX \longrightarrow {}_{Z-2}^{A-4}X' + {}^4_2\alpha$		Parent	Daughter Alpha Particle
Beta decay	${}^0_{-1}\beta$	${}_Z^AX \longrightarrow {}_{Z+1}^AX' + {}^0_{-1}\beta$		Parent	Daughter Beta Particle
Positron emission	${}^0_{+1}\beta$	${}_Z^AX \longrightarrow {}_{Z-1}^AX' + {}^0_{+1}\beta$		Parent	Daughter Positron
Electron capture	X rays	${}_Z^AX + {}^0_{-1}e \longrightarrow {}_{Z-1}^AX' + \text{X ray}$		Parent Electron	Daughter X ray
Gamma emission	${}^0_0\gamma$	${}_Z^AX^* \xrightarrow{\text{Relaxation}} {}_Z^AX' + {}^0_0\gamma$		Parent (excited nuclear state)	Daughter Gamma ray
Spontaneous fission	Neutrons	${}_Z^{A+B+C}X \longrightarrow {}_Z^AX' + {}_Y^BX' + {}^1_0n$		Parent (unstable)	Daughters ENERGY Neutrons

# Ionizing Radiation Dose

- **Radiation absorb dose (RAD):** the amount of energy absorbed by the body.  $1 \text{ cGy} = 0.01 \text{ J/kg}$  (USA)
- **Gray (Gy):** expressed as absorbed energy per unit mass of tissue.  $100 \text{ rad} = 100 \text{ cGy} = 1 \text{ J/kg}$  (SI)
- **Roentgen Equivalent Man (REM)** relates the absorbed dose in human tissue to the effective biological damage of the radiation (USA)
- **Sievert (Sv):** the absorbed dose in human tissue to the effective biological damage of the radiation (SI)

# Radioactivity Biological And Effective Half-lives

- ⦿ Biological half-life is the time to remove half of radioactive element from body
- ⦿ Effective half-life is the combined effect of radioactive decay & biological elimination
- ⦿ Effective half-life is always shorter than either physical or biological half-lives



# Biological Effects of Ionizing Radiation

- ⦿ Direct damage

- ⦿ Chromosome

- ⦿ Other biochemical

- ⦿ E.g. alpha and beta particles

- ⦿ Indirect damage

- ⦿ Chemical changes due to radiolysis of water in cell

- ⦿ E.g. Gamma and neutron

# Effects of Radiation

## ⦿ **Deterministic effect**

- ⦿ Set by a threshold below which no clinical effect is seen followed by a steady rising dose-effect curve
- ⦿ Generally manifest in days to weeks

## ⦿ **Stochastic effect**

- ⦿ No threshold dose
- ⦿ Take months to years

# **Contamination vs Exposure**



## Internal Contamination

- Swallow or breathe in radioactive materials
- Through an open wound or are absorbed through the skin

<https://emergency.cdc.gov/radiation/contamination.asp>



## External Contamination

- Dust, powder, or liquid radioactive material comes into contact with a person's skin, hair, or clothing

<https://emergency.cdc.gov/radiation/contamination.asp>





## Radioactive Contamination

Radioactive material is deposited on or in an object or a person

<https://emergency.cdc.gov/radiation/contamination.asp>



## Radiation Exposure

Patient expose to the radiation or the energy emitted by the radioactive material

This energy penetrate the body

<https://emergency.cdc.gov/radiation/contamination.asp>

# Acute Radiation Syndrome

- ⦿ An acute illness caused by irradiation of the entire body (or most of the body) by a high dose of penetrating radiation in a very short period of time (usually a matter of minutes)
- ⦿ The major cause of this syndrome is depletion of immature parenchymal stem cells in specific tissues: Bone marrow and epithelial cells covering skin, GI and endothelium
- ⦿ Most cause of death 60-days post exposure

# Requirements For ARS To Occur

- ⦿ High radiation dose
- ⦿ The dose usually must be external
- ⦿ The radiation must be penetrating (able to reach the internal organs)
- ⦿ Involving most of the body
- ⦿ The dose delivered in a short time (minutes)

<https://emergency.cdc.gov/radiation/arsphysicianfactsheet.asp>

# Events that can cause ARS

- ⦿ Nuclear detonation: weapons, improvised nuclear devices
- ⦿ Radiological dispersal devices, dirty bombs
- ⦿ Nuclear power plant/ reactor incidents
- ⦿ Radiological exposure devices
- ⦿ Transportation incidents

<https://emergency.cdc.gov/radiation/arsphysicianfactsheet.asp>



# Nuclear detonation: weapons, improvised nuclear devices

An Improvised Nuclear Device (IND) is a type of nuclear weapon. When an IND explodes, it gives off four types of energy: a blast wave, intense light, heat, and radiation. The bomb dropped on Hiroshima, Japan, at the end of World War II is an example of an IND.

When an IND explodes, a large fireball is created. Everything inside of this fireball vaporizes and is carried upward. This creates a mushroom-shaped cloud. The material in the cloud cools into dust-like particles and drops back to the earth as **fallout**. Fallout can be carried by the wind and can end up miles from the site of the explosion. Fallout is radioactive and can contaminate anything it lands on.



# Radiological dispersal devices, dirty bombs

## What is a dirty bomb?

A dirty bomb is a mix of explosives, such as dynamite, and radioactive powder or pellets. It is also known as a radiological dispersal device (RDD).



A dirty bomb cannot create an atomic blast.

RADIOACTIVE MATERIAL



When the bomb explodes, the blast carries radioactive material into the surrounding area.



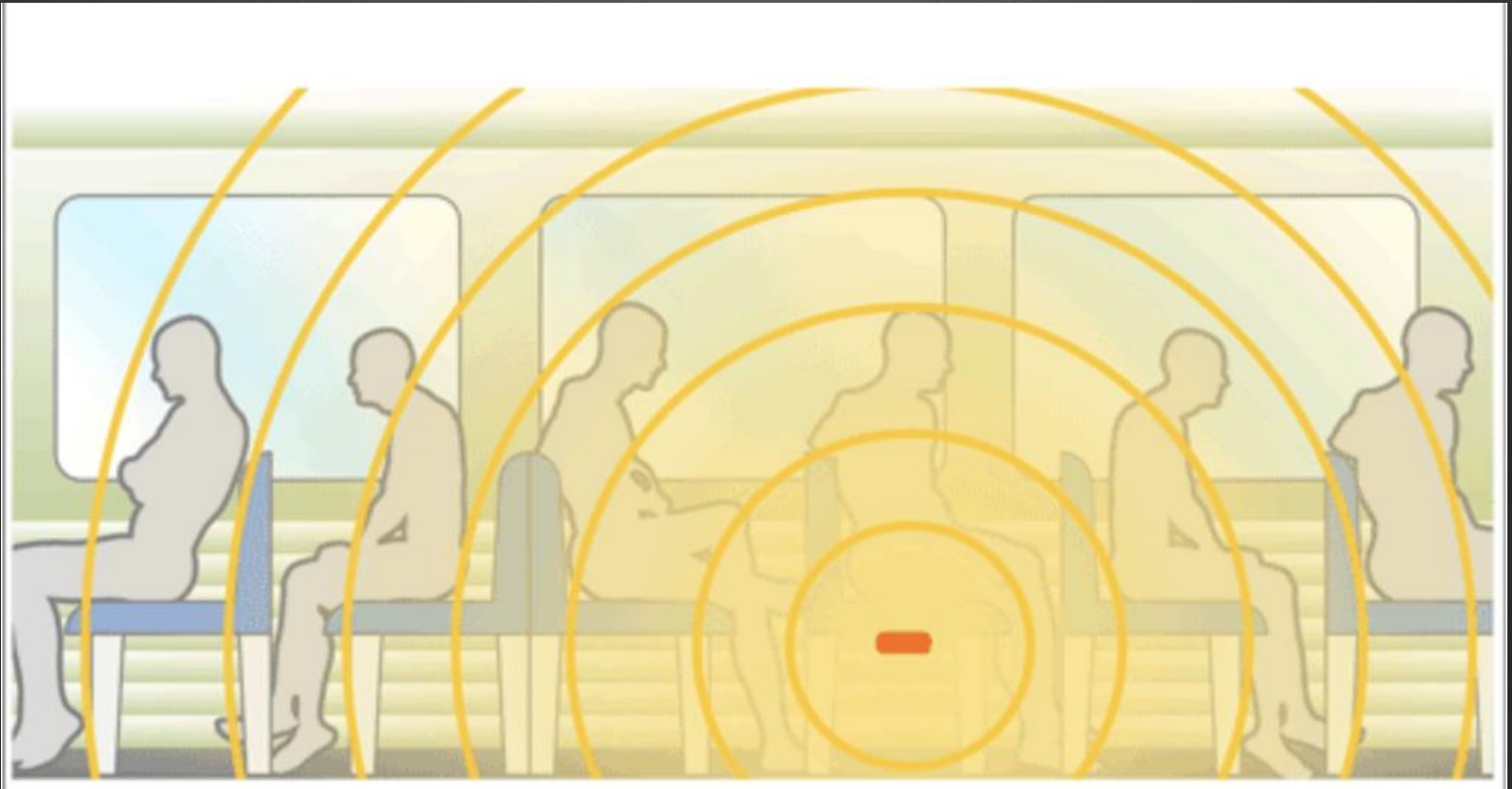


# Nuclear power plant/ reactor incidents



Fukushima Daiichi Nuclear disaster, March 2011

# Radiological exposure devices



Hidden and unsealed radioactive device

[http://www.remm.nlm.gov/red\\_metro.htm](http://www.remm.nlm.gov/red_metro.htm)

# Classic ARS Syndrome

- ⦿ Hematopoietic (Bone Marrow) syndrome (Dose Range 0.7-10 Gy)
- ⦿ Gastrointestinal Syndrome (Minimum Dose of 6-10Gy)
- ⦿ Cardiovascular/Central Nervous System Syndrome (Minimum Dose of 20 Gy)



# Stages of ARS

- ⦿ Prodromal stage
- ⦿ Latent stage
- ⦿ Manifest Illness stage
- ⦿ Recovery or Death

# Hematopoietic Syndrome

Dose	Prodromal stage	Latent stage	Manifest illness stage	Recovery
>0.7 Gy	<ul style="list-style-type: none"> <li>Anorexia, nausea &amp; vomiting</li> <li>Onset 1h-2d after exposure</li> <li>Lasts for minutes to days</li> </ul>	<ul style="list-style-type: none"> <li>Stem cells in bone marrow are dying</li> <li>Patient may appear and feel well</li> <li>Lasts 1-6 weeks</li> </ul>	<ul style="list-style-type: none"> <li>Anorexia, fever, and malaise</li> <li>Drop in all blood cell counts</li> <li>Primary cause of death are infection and hemorrhage</li> <li>Survival decrease with higher doses</li> <li>Most death occur within a few months of exposure</li> </ul>	<ul style="list-style-type: none"> <li>In most cases bone marrow cells will begin to repopulate the marrow</li> <li>Full recovery for a large % age of individuals (few weeks to 2 years)</li> </ul>

# GI Syndrome

Dose	Prodromal stage	Latent stage	Manifest illness stage	Recovery
<p>&gt;10 Gy (&gt;1000rads) Some symptoms may occur as low as 6 Gy or 600 rads</p>	<ul style="list-style-type: none"> <li>• Anorexia, severe nausea &amp; vomiting, cramps, and diarrhea</li> <li>• Onset occurs within a few hours after exposure</li> <li>• Lasts about 2 days</li> </ul>	<ul style="list-style-type: none"> <li>• Stem cells in bone marrow and cells lining GI tract are dying</li> <li>• Patient may appear and feel well</li> <li>• Lasts less than 1 week</li> </ul>	<ul style="list-style-type: none"> <li>• Malaise, Anorexia, fever, severe diarrhea, dehydration and electrolyte imbalance</li> <li>• Death due to infection, dehydration and electrolyte imbalance.</li> <li>• Death occurs within 2 weeks of exposure</li> </ul>	

# Cardiovascular/Central nervous system Syndrome

Dose	Prodromal stage	Latent stage	Manifest illness stage	Recovery
<p>&gt;50 Gy (5000 rads)</p> <p>Some symptoms may occur as low as 20 Gy or 2000 rads</p>	<ul style="list-style-type: none"> <li>• Extreme nervousness and confusion, severe nausea &amp; vomiting, and watery diarrhea. Loss of consciousness; and burning sensations of the skin</li> <li>• Onset occurs within minutes after exposure</li> <li>• Lasts for minutes to hours</li> </ul>	<ul style="list-style-type: none"> <li>• Stem cells in bone marrow and cells lining GI tract are dying</li> <li>• Patient may appear and feel well</li> <li>• Lasts less than 1 week</li> </ul>	<ul style="list-style-type: none"> <li>• Malaise, Anorexia, fever, severe diarrhea, dehydration and electrolyte imbalance</li> <li>• Death due to infection, dehydration and electrolyte imbalance.</li> <li>• Death occurs within 2 weeks of exposure</li> </ul>	<ul style="list-style-type: none"> <li>• No recovery is expected</li> </ul>

# Cutaneous Radiation Syndrome (CRS)

- ⦿ Acute radiation exposure to the skin large doses of ionizing radiation
- ⦿ without systemic effects of ARS
- ⦿ Inflammation, erythema and dry desquamation
- ⦿ Epilation due to hair follicles damage
- ⦿ Few days-several weeks: intense redness, blistering and ulceration, necrosis



# Cutaneous Radiation Syndrome (CRS)



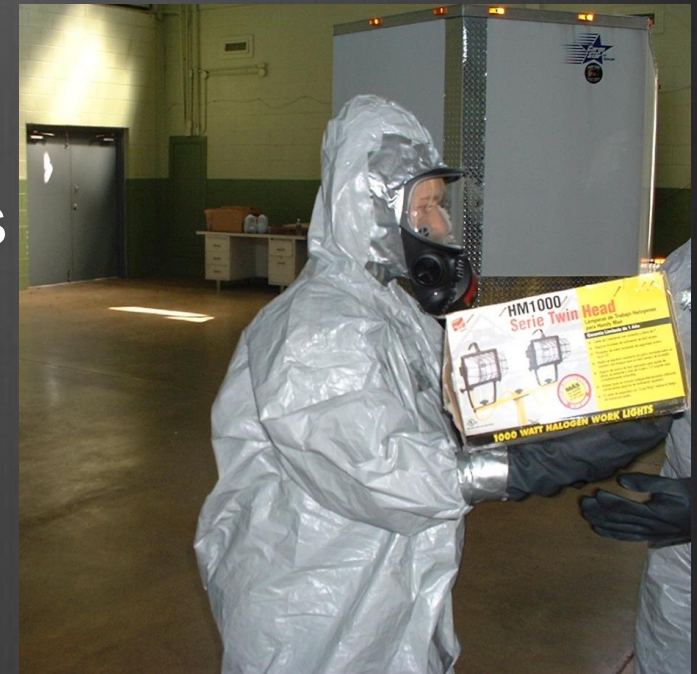
# Radiation Detection

- ⦿ Survey meters
- ⦿ Survey meters should ideally detect  $\alpha$ ,  $\beta$ , and  $\gamma$  radiation.
- ⦿ A pancake probe is the most commonly used device for surveying potentially contaminated patients for all 3
- ⦿ More modern units have been reduced in size for one-handed, digital and simple operation



# Personal Protective Equipment

- ⦿ **Level C:**  
Radiological dispersal devices



- ⦿ **Level D:**  
Radiological exposure devices

# Decontamination

- ⊗ Cloths removing: removes the majority of contamination
- ⊗ Wet decontamination employs tepid water, liquid soap.
- ⊗ End point of decontamination:
  - $< 2x$  background after decontamination
- ⊗ Have patient lean forward to wash hair to keep runoff out of eyes and face
- ⊗ Cover wounds to avoid contamination

# Diagnosis: Hematopoietic Syndrome

- Serial complete blood counts (CBC)
  - With differential white blood cell (WBC) count
    - Absolute Lymphocytes Count**
      - Critical for determining degree of ARS
      - Every 2-3 hours during the first 8 hours post exposure
      - Every 4-6 hours for the following 2 days
  - With platelet count

Advanced Hazmat Life Support Provider Course @ University of Arizona



# Diagnostic tools

## Dose Estimator for Exposure: 3 Biodosimetry Tools

[Define Biodosimetry](#) | [What You Need to Know about Biodosimetry: The Basics](#) | [About This Tool/Credits](#) | [Disclaimer](#)  
[Four References Comparing Biodosimetry Tools](#) | [REMM Biodosimetry Reference List](#) | [What is exposure?](#)



[Time to  
Onset of Vomiting](#)




[Lymphocyte  
Depletion Kinetics](#)



[Dicentric  
Chromosome Assay](#)


# Time to onset of vomiting

**1. Time to Onset of Vomiting**


 [Warning](#)

[Background](#) | [Illustrations](#) | [References](#)


**1. Date/time exposure began**



(e.g., 01/22/2008, 14:25)



**2. Date/time vomiting began**



**3. ☐ Estimate dose from exposure**

**4. Dose estimate**


[Gy](#)

[95% confidence limits](#)

[Gy](#)


# Lymphocyte Depletion Kinetics

**2. Lymphocyte Depletion Kinetics**


 **Warning**

[Background](#) | [Illustrations](#) | [References](#)


**1. Date/time exposure began**





(e.g., 01/22/2008, 14:25)




**2. Date/time of one or more blood counts**







(e.g., 01/22/2008, 23:00)

**Lymphocyte count**  
(x 10<sup>9</sup> cells/L) 

(e.g., 1.25)

**3.  from exposure**

**4. Dose estimate**

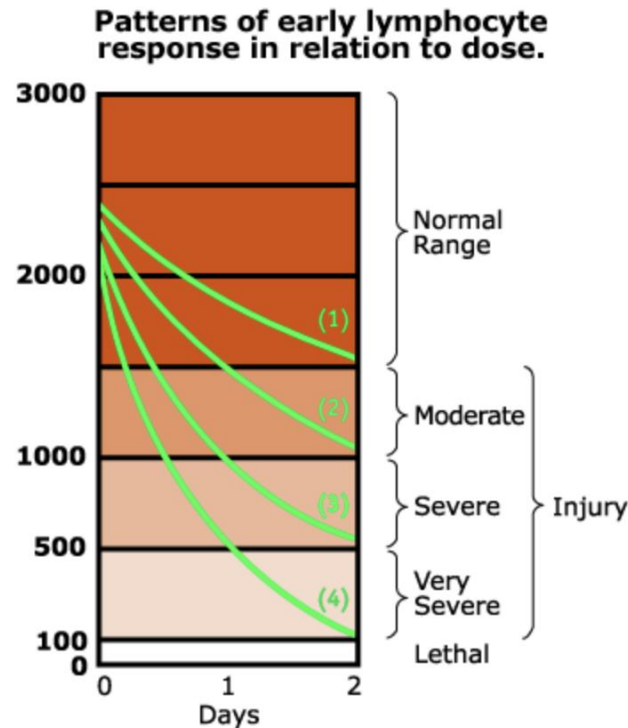
[Gy](#)

[95% confidence limits](#)

[Gy](#)

# Andrews lymphocyte depletion nomogram

## Andrews Lymphocyte Depletion Curves



- Classical Andrews lymphocyte depletion curves and accompanying clinical severity ranges
- Curves 1-4 correspond roughly to the following whole-body doses:
  - Curve 1 - 3.1 Gy
  - Curve 2 - 4.4 Gy
  - Curve 3 - 5.6 Gy

# Treatment

- ⦿ ABC's and vital signs, urine output monitoring
- ⦿ Treat major burns, trauma, and respiratory injury if present – within 48 hours
- ⦿ Attend to contaminated wounds
- ⦿ Surgery should ideally be done within 36 hours
- ⦿ If exposure within 8 to 12 hours, repeat cbc every 2 hours times 3 to assess lymphocyte depletion; otherwise, q4-6h x 2 days



# Treatment

- ⊗ Treat vomiting with antiemetic
- ⊗ Pay careful attention to fluid and electrolyte balance
- ⊗ Prevent and treat infections. Isolation might be required to prevent infection
- ⊗ Provide psychological support
- ⊗ Consult your local radiation exposure agency

# Medical Management of ARS

1-2 Gy	2-4 Gy	4-6 Gy	6-8 Gy	>8Gy
<ul style="list-style-type: none"><li>• Supportive care</li></ul>	<ul style="list-style-type: none"><li>• Antibiotics</li><li>• Blood and platelets as needed</li><li>• Colony stimulating factors (CSF)</li><li>• Isolation days 10-20</li></ul>	<ul style="list-style-type: none"><li>• Isolation day one</li><li>• Antibiotics, IV fluids</li><li>• Blood and platelets as needed</li><li>• Colony stimulating factors (CSF)</li><li>• Gut bacterial prophylaxis</li></ul>	<ul style="list-style-type: none"><li>• Same as 4-6 Gy</li><li>• Consider stem cell transplant</li></ul>	<ul style="list-style-type: none"><li>• Palliative care</li></ul>

# Summary

- ⦿ Radiation exposure is not immediately life threatening
- ⦿ Patients die from ARS due to complications following the exposure
- ⦿ Supportive care is the main stay of treatment for ARS